SPRUCE BUDWORM CONTROL
IN OREGON AND WASHINGTON
1949 - 1956

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
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By

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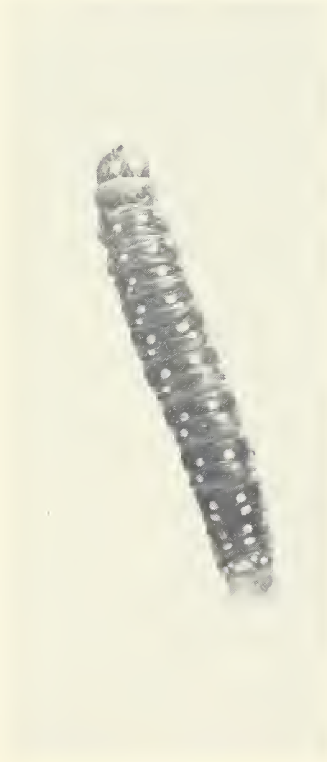
PLATE I. LIFE STAGES OF THE SPRUCE BUDWORM

Adult x4

Egg masses x4



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INTRODUCTION

The spruce budworm [1/] is one of the most widely destructive forest insects in North America. Periodic outbreaks of the budworm in eastern Canada and northeastern United States date back at least to 1807 (16). They have often continued for periods of 10 or more years and have resulted in tremendous timber losses. The first recorded outbreak in western North America occurred in British Columbia in 1909 (13).

While epidemics of the spruce budworm raged in other portions of the continent, a unique situation existed in the states of Oregon and Washington for over a quarter of a century. From 1914 when the budworm was first recorded from Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) at Ashland, Oregon, to 1943 when the first extensive outbreak developed in northeastern Washington, only small, localized, and widely separated infestations occurred in various forests in the eastern parts of the two states. All of these outbreaks subsided from natural causes without any appreciable loss of timber. This is quite remarkable in view of the well-known destructive potential of the budworm and the vast amount of host material present in the two states.

During this period, no control measure was known and none was considered necessary. The budworm was just another insect in the forests of Oregon and Washington.

1/ *Choristoneura fumiferana* (Clem.)

Since 1944, the picture has changed. The spruce budworm is no longer ignored. Over $4 million has been spent to treat 3,840,000 acres of epidemic infestations in Oregon and Washington during a seven-year period from 1949 to 1955. The program is an outstanding example of wholehearted cooperative effort by private, state, and federal timber owners and land-managing agencies in combating a common enemy.

In undertaking control of the spruce budworm, we drew heavily on experimental work conducted in northeastern United States and Canada. Some of our techniques have since found application in similar control programs in Canada and in other portions of the United States.

Extensive tree killing by the budworm has been prevented and the practicability of aerial spraying to control this defoliator has been proved. It can be safely stated that the program has saved the highly important Douglas-fir industry of the Pacific Northwest from destruction by the spruce budworm.

Control operations were suspended in 1956 because the presence and abundance of natural control factors indicated that the epidemic might subside without further treatment. The budworm is being carefully watched and aerial spraying operations will be resumed if necessary.

BACKGROUND

Forest Resources

The states of Oregon and Washington are located in the northwestern portion of the United States and comprise the Pacific Northwest Region of the U. S. Forest Service. This region has a total forest-land area of 54 million acres, five-sixths of which is classed as commercial forest land. After several decades of heavy utilization, the region still has some 18 million acres of old-growth sawtimber.

About 38 percent of the live sawtimber volume in the continental United States is found in the Pacific Northwest. This region furnishes more than one-quarter of all forest products consumed in the United States each year. More than one-quarter of a million people depend upon the wood-using industries of the two states for their direct

livelihood. Because of these facts, control of the spruce budworm became a matter of paramount importance both locally and nationally.

The Cascade Mountain Range divides the Pacific Northwest region into two distinct forest types. Forests of the western portion are predominantly Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), with western hemlock (Tsuga heterophylla (Raf.) Sarg.), Sitka spruce (Picea sitchensis (Bong.) Carr.), western redcedar (Thuja plicata Donn.), and some of the true firs (Abies) as associated species. In the eastern portion, ponderosa pine (Pinus ponderosa, Laws.) predominates, and lodgepole pine (Pinus contorta Dougl.), Douglas-fir, white fir (Abies concolor (Gord. & Glend.) Lindl), and western larch (Larix occidentalis Nutt.), are other species of appreciable occurrence.

Host Plants

In western North America the budworm has caused its greatest economic damage to Douglas-fir, true firs, and Engelmann spruce (Picea engelmannii Parry). A closely related species, Choristoneura pinus Free. has caused severe damage to jack pine (Pinus banksiana Lamb.) and Scotch pine (Pinus sylvestris L.) in the Lake States. Ponderosa and lodgepole pine in western United States have been severely defoliated by another form of the budworm. Hemlock, larch, and other conifers, when associated with preferred hosts, are also partially defoliated by the budworm.

Habits of the Spruce Budworm

The spruce budworm overwinters as 2nd instar larvae beneath bark scales, lichen, and other protective material on roughened portions of limbs and trunks of the host trees. Upon emerging from hibernation in the spring, the tiny larvae enter and mine one needle of the previous year's growth. When the buds start to swell, larvae leave the needles and enter the expanding buds where they feed on the developing foliage. During the 4th and 5th instars, two or more branch tips are tied together to form crude nests within which the larvae feed. New growth is preferred and is almost entirely consumed before older needles are eaten. After passing through 6 instars, larvae are mature and pupate in the webbed branchlets. There is considerable evidence that at elevations above 5000 feet, budworms often have a two-year life cycle. After reaching the 4th larval instar, they hibernate for a second winter and complete their development during the following year.

Two or more years of heavy defoliation are usually required before appreciable stand mortality occurs. However, the budworm often kills small trees in one year when complete defoliation takes place.

Factors Influencing Control Decisions

Because the budworm is concealed for so long a period during its life cycle, direct control measures must be critically timed. Insecticides must be applied to coincide with the short period of general feeding of 4th, 5th, and 6th instar larvae preceding pupation. During this feeding period, larvae are exposed and vulnerable.

In addition to the uncertainty of scheduling control operations, other problems are:

(1) It is difficult to determine if control measures are necessary. Many epidemics are extremely destructive; others subside without causing appreciable damage.

(2) Infestation cycles are usually long, indicating that one treatment may not be sufficient to bring an outbreak under control.

(3) Stands needing treatment range widely in current value, hence the amount of money justified to protect them from destruction varies.

CONTROL THROUGH AERIAL SPRAYING

The present epidemic was discovered in its early stages in 1944 on the Umatilla National Forest in northeastern Oregon. Although no accurate measures of the intensity or increase of this outbreak were made from 1944 to 1946, it was evident that a balance of natural factors, which had kept this defoliator under control, had been upset. A full-fledged epidemic was in progress.

Spruce Budworm Surveys

Reliable surveys are necessary for evaluating forest pest control needs. In 1947, the need for detailed information on the extent and severity of budworm infestations led to initiation of an annual regional survey program in the Pacific Northwest. Private, state, and federal agencies have cooperated in this survey.

In Oregon and Washington aerial surveys (17) are conducted from about July 1 to September 15 to locate and map-in-place all epidemic centers of spruce budworm infestations. Since 1949, the entire 45 million acres of commercial forest land in the two states has been re-surveyed annually by a combination of gridiron and contour flying. We use a high-wing plane of the Cessna 180 type, two trained observers, and a pilot well versed in mountain flying. Most surveys are conducted 800 to 1000 feet above the tree tops. Our aerial survey findings are carefully ground checked. These checks verify the identity of the insect or cause of damage, and the degree of damage, and determine more accurately the infestation boundaries.

Intensive ground surveys to locate incipient budworm infestations, not detectable from the air, have also been conducted throughout the western part of the region since 1949. An average of 2000 plots has been examined each year by cooperating foresters. At the end of each season a detailed report of survey findings is prepared and distributed to all interested parties.

The first surveys, in 1947, revealed 907,000 acres of spruce budworm epidemic infestation in the two states. In 1948, infestations were recorded on 1,446,000 acres, with sizeable outbreaks occurring for the first time in the extensive, high-value Douglas-fir forests of western Oregon. At the peak of the epidemic in 1949, some 2,276,000 acres were heavily infested, and the budworm was present in some degree in practically all fir stands of the two states.

Experimental Basis for Aerial Spraying

By the fall of 1947, timber owners and managers in Oregon and Washington faced a serious problem. Budworm populations had reached epidemic proportions on nearly one million acres. Much of the attacked timber was dying; some had died; and the entire Douglas-fir industry of the Pacific Northwest was seriously threatened. And, due to the peculiar habits of the budworm, no wholly dependable control method under forest conditions had yet been evolved. Something had to be done, and soon.

It is interesting to note that the first attempted spruce budworm control by spraying in western United States was in 1929 in Shoshone National Forest, Wyoming (9). A small experiment using lead arsenate applied with fire hoses and pumps from the ground showed that

larvae could be killed in lower portions of trees when buds were fully opened. However, this method was not satisfactory under forest conditions.

The heavy budworm populations in the Pacific Northwest afforded an excellent opportunity for practical tests of the results of small-scale, direct-control studies undertaken between 1945 and 1947 in Canada and the northeastern states (2, 7). Insecticides containing DDT, tested against light to moderate budworm populations, gave promise but results were not conclusive. However, these same insecticides were very effective against the Douglas-fir tussock moth, _Hemerocampa pseudotsugota_ McD., in Idaho in 1947. Thus, the stage was set for a noteworthy experiment.

From May to August 1948, a large-scale, cooperative aerial spraying experiment [2/] was undertaken against the spruce budworm in eastern Oregon to test the most promising control techniques available at that time (8). Twelve 350-acre plots were treated with DDT--fuel oil solutions using dosages of 1/2, 1, and 2 pounds of DDT per acre. Two similar plots were established as check areas. A biplane (Travelaire 4000) and a helicopter (Bell 47B-3), were used to apply the insecticides. Both were effective, but the biplane was cheaper.

This experiment proved that heavy epidemic budworm populations could be successfully and economically killed by the aerial application of an insecticide containing 1 pound of DDT per acre. Upwards of 95 percent control was obtained when spraying was done during quiet morning hours and against late larval stages of the budworm when feeding on expanding foliage. For the first time, entomologists had a practical, effective, and economical method of controlling this defoliator.

It was one thing to demonstrate that the budworm would be killed by aerial spraying on a plot basis and still another to plan, finance, and conduct a full-scale control project. However, this important experiment provided the stimulus for undertaking control and developed techniques for spraying, sampling budworm populations, and evaluating control that have been closely followed during the entire program.

2/ This experiment was undertaken near Heppner, Oregon, by the former U. S. Bureau of Entomology and Plant Quarantine in cooperation with the Oregon State Board of Forestry, U. S. Forest Service, and Kinzua Pine Mills Company.

Spruce Budworm Action Committee

By 1948 the budworm was so widely distributed and affected so many ownerships that no one organization could control it. Federal, state and private cooperation and financing were urgently needed.

In the fall of 1948, representatives of all affected agencies, companies, and individuals met to consider survey findings and the pressing problem of spruce budworm control. A Spruce Budworm Action Committee was organized, which felt that control should be undertaken by administrative agencies existing in the two states. A control plan was prepared initiating action against centers of infestation that provided the greatest immediate threat to our timber resources. Similar meetings have been held each year and detailed control plans (14) prepared for each annual project by this informal group, now called the Northwest Forest Pest Action Committee. 3/

At its first meeting, the Committee felt that direct control should be aimed at obtaining 100 percent kill and should be undertaken only as an emergency measure to protect specific values until natural factors again suppressed the epidemic. While it might have been desirable to treat all centers of infestation immediately, technical and practical difficulties such as shortage of time, lack of available equipment and qualified operators, and uncertain quantities

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3/ The Northwest Forest Pest Action Committee is composed of numerous private individuals and representatives of the following organizations:

Associated Forest Industries of Oregon, Industrial Forestry Association, Keep Oregon Green Association, Keep Washington Green Association, Oregon Extension Service, Oregon Forest Fire Association, Oregon State Board of Forestry, Oregon State College, Southern Oregon Conservation and Tree Farm Association, State College of Washington, Tree Farm Management Service.

Also represented are U.S. Bureau of Land Management, U.S. Forest Service, U.S. Office of Indian Affairs, U.S. Soil Conservation Service, University of Washington, Washington Forest Fire Association, Washington State Division of Forestry, Washington State Forestry Conference, Western Forest Industries Association, Western Forestry and Conservation Association, Western Pine Association.

Many forest industry companies and forest consulting firms also are represented.

of insecticide made this impractical. Therefore, priorities were established for each project in keeping with the following strategy:

(1) to protect high-value forests of western Oregon and western Washington, regardless of infestation intensities;

(2) to treat centers of epidemic infestation near previously controlled units, to prevent reinfestation of these units;

(3) to protect stands in which tree-killing is imminent within one or two years.

This strategy has been followed during the entire program. It should be mentioned that in 1951 the spruce budworm problem in parts of eastern Oregon and Washington became complicated by a widespread, aggressive outbreak of the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk. Weakened by repeated budworm defoliation, tremendous numbers of trees on both sprayed and unsprayed units were killed. This situation resulted in two changes in planning budworm control:

(1) In budworm infested stands threatened by the beetle, control was conducted sooner in the outbreak than would have otherwise been done, in order to protect the resource fully.

(2) In budworm infested stands attacked by the beetle, further heavy expenditures for budworm control were postponed until the beetle epidemic was controlled.

At first we did not know how many acres could be treated in one season. We needed a practical operation but not one so large that failure would be disastrous. Therefore, the first control project in 1949 covered only 267,000 acres. As a result of this experience we were able to increase the acreage treated to 933,000 acres in 1950 and 927,000 acres in 1951.

Development of Operational Methods

Need for adequate research on entomological as well as operational phases of spruce budworm control was recognized early in the program. Of necessity, operational problems received most attention.

While the control projects from 1949 to 1952 were in progress we tried to improve methods by conducting one major operational experiment each year. We tested the possibility of prolonging treating periods by spraying with DDT, Benzene Hexachloride, and Toxaphene against migrating 1st instar larvae to prevent one year's defoliation. These tests were unsuccessful. We studied the possibility of lowering direct control cost by using Dieldrin and Toxaphene and by reducing the amount of DDT to 3/4, 1/2 or 1/4 pounds per gallon. These insecticides were also applied at the rate of 1 gallon per acre. The results showed that insecticides containing less than one pound of DDT per acre or containing other chemicals, gave unsatisfactory control on a unit or project basis (1, 3).

We also tested the application of insecticide on a large control unit from heights above those prescribed for previous projects. The relative effectiveness of a Martin TBM at 100 and 400 feet above the treetops was investigated in interest of pilot safety. The results (5) showed that, with this particular plane, control was just as effective at 400 feet as at 100 feet. Before raising the spraying heights for other types of planes, additional tests must be conducted.

Safety

Safety was stressed throughout. The hazards inherent in this work required detailed analysis and precise action plans covering aerial and ground operations on each project. Contracts included many provisions to safeguard all phases of control operations. These provisions were the results of recommendations based on experiences of the administrative agencies involved, the aerial-spraying industry, the State Boards of Aeronautics, and the Civil Aeronautics Administration. All personnel were instructed in safety and frequent informal safety meetings were held at each airstrip during operations.

The first project in 1949 was accident free. During the control work of 1950, 1951, and 1952 there were 10 pilot fatalities, however, which marred our success in controlling the budworm and saving our forest resources. Since 1952 there have been no fatalities and only one serious accident.

Each accident was thoroughly investigated and reported so that similar occurrences could be avoided on subsequent projects. Safety clauses in the contracts were strengthened and rigid specifications covering pilot experience and training were strictly enforced. As a

result, a more desirable safety record has been achieved on these hazardous undertakings.

Project Financing

Money to conduct these control projects was, of course, a major requirement. In accordance with the Insect Pest Control Acts of Oregon and Washington, State Foresters declared zones of infestation that included units proposed for treatment. Thus, all timberland owners within the zones were required to pay a portion of control costs. The two State Legislatures approved emergency appropriations for their shares. Almost as soon as control plans were announced, large private companies in the affected units assured their support by making financial contributions. However, since the bulk of infested acreage was publicly owned, it was imperative that federal funds be made available and in time to adequately prepare for and conduct each project.

Federal participation was carried out under provisions of Public Law 110, known as the Forest Pest Control Act. This Act recognizes federal responsibilities in controlling forest insects on lands in all ownership classes. The intent of the Act is to stimulate cooperation between private, state, and federal agencies in conducting surveys to detect and appraise forest insect outbreaks, and in controlling them. It authorizes the Secretary of Agriculture to require contributions as a condition to federal participation in control operations on state and privately owned lands.

The 1947 Douglas-fir Tussock Moth Control Project in Idaho was the first cooperative project conducted under provisions of this act. Results were highly successful and set a pattern for larger control projects that followed.

Cost Participation

An equitable cost-participation formula for budworm control was developed and agreed upon. This formula provided that:

(1) public agencies pay the entire cost of treating publicly-owned lands,

(2) private owners pay 25 percent of the cost of treating their own lands, and

(3) 50 percent of the cost of treating private lands be borne by the state and 25 percent by the Federal Government.

In 1951 the Oregon Legislature decreed that private owners in Oregon should pay 37-1/2 percent and the State pay 37-1/2 percent of control costs on privately-owned lands. Otherwise, control expenditures have been apportioned by the original formula.

When administrative costs were added to those of contracted services, the cost of the projects ranged from \$.93 to \$1.20 per acre. The seven projects have averaged \$1.05 per acre.

Project Administration

Administration of all control work has been divided between the Oregon State Board of Forestry and the United States Forest Service, except in 1951 when the Washington State Division of Forestry administered a small project in that state. Normally, the State agencies administered those units containing a high percentage of private land and the Forest Service administered units containing mostly federal lands. On most units, ownerships were intermingled. Cooperative agreements between the Federal Government and the two states were formulated and agreed upon each year. These agreements provided for spraying and reimbursements for treating lands of all ownerships within the units administered by each agency.

Detailed plans of operation were prepared by the administrative agencies (12, 15). These plans outlined job descriptions and the responsibilities and duties of each worker. As many as 275 men were sometimes required to properly execute all phases of a single project. Prior to the start of spraying, insecticide and gasoline storage tanks were filled, telephone and short-wave radio communication systems installed, mobile and fixed weather stations manned, field headquarters established, search and rescue squads organized, and doctors and hospitals alerted.

Airfields

Suitable airfields and sites for construction of airstrips were selected by administrative agencies well in advance of issuing bid invitations so that contractors could inspect them and compute costs prior to bidding. All airstrips had to be accessible to tanker trucks and close to control unit centers.

Whenever possible, either regulation airfields with paved landing strips or approved emergency landing fields were used. However, many airstrips were constructed on leased private land or publicly owned lands. Grain fields, hay fields, large rock flats, and old burns were used. Some airstrips cost as much as $18,000 to construct. Fortunately, some of these were used for more than one year. It was necessary to remove snow from many airstrips early each spring in order for them to dry out, and be ditched and graded well in advance of spraying. As many as 15 airfields were in operation during a single year.

Bids for Services and Materials

Materials and services were obtained by competitive bidding with awards made to private concerns submitting the lowest qualified bids. To have proper control over materials and services, each agency issued three separate bids on each project for:

(1) formulated insecticide,

(2) transportation and storage of insecticide and pumping facilities at each airfield, and

(3) application of the insecticide on each control unit.

Formulated insecticide was purchased ready to use. For 6 of our 7 projects the insecticide consisted of a solution containing 1 pound of technical grade DDT dissolved in 1.2 quarts of a hydrocarbon solvent, and diluted to one gallon with fuel oil. In 1951 specifications for insecticide differed in two respects from those used in 1949 and 1950. Only 0.75 pounds of DDT was required and provisions made for the use of a solvent alone in the formula. Due to a somewhat lower insect mortality on the 1951 project, the original formula was specified for the 1952 and subsequent projects. Insecticide was applied at a rate of one gallon per acre. Costs of insecticides ranged from 32 to 69 cents per gallon, depending upon availability of DDT and other factors.

Transportation of insecticide was provided by tanker truck. Two methods were used in storing insecticide. Before airfield storage tanks were set up, the insecticide was trucked from a processing plant in Portland, Oreg., to intermediate field storage tanks. When spraying started, it was trucked to airfields, either directly from Portland or from the intermediate storage tanks. Airfield tanks

were promptly filled at the end of each spraying day. Costs for this service and all pumping facilities averaged 11 cents per gallon.

Application of insecticide has been by many different types of aircraft, including military training planes, dive bombers, twin-engine and tri-motor cargo planes, and helicopters. 4/ However, most of the control units have been sprayed by Stearman bi-planes powered with 450 HP motors carrying 120 to 145 gallons and by Ford tri-motor planes carrying 400 to 600 gallons. In determining the number of spray planes needed to treat a given unit, we have used the Stearman with a 450 HP motor as the base spray plane. One Stearman has been figured to treat 10,000 or more acres on a control unit. One Ford tri-motor has been equivalent to 3 Stearmans. One B-18 or one TBM has been equivalent to 4 Stearmans. As many as 85 single-engine planes, 8 multi-engine planes and 25 stand-by planes have been used on a single project.

Generally, single-engine and Ford tri-motor planes have been used on units with rough, steep terrain and deeply dissected canyons and on units intermingled with agricultural lands. Other multi-engine planes, less maneuverable than the Fords, have been used on units having flatter terrain and where spraying runs of 10 or more miles were possible. Costs of contract spraying have ranged from 21 to 58 cents per acre depending on the type of plane used, ferrying distances between airfields and control units, and topographic features of the unit.

Photographs, Maps, and Mosaics

Aerial photographs and maps were indispensable. A staggering number of paired photographs at a scale of 1:20,000 were purchased from all available sources and used during this program. Early in the fall of each year, men began the tedious task of preparing them for field use. Section corners were plotted on each photograph, and openings and non-infested timber types of more than 160 acres in size were outlined and deleted from the project. Then control units

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4/ The following single engine aircraft have been used: Douglas SBD, Fairchild 71, Fokker Super Universal, Martin TBM, N-3-N, Stearman PT-17, Stinson SM7A, Travelaire 4000, Vultee BT-13, and Waco. The following multi-engine aircraft have been used: Boeing 247, Cessna T-50, Douglas B-18, Douglas C-47, and Ford tri-motor. Bell 47B-3 helicopters have been used to a limited extent.

were divided into individual spray blocks of 1000 to 5000 acres in size, using natural boundaries that could be easily recognized by spray pilots, and spray acreage and gallons of insecticide for each block and unit were computed. Photographs were also used in negotiating final acreag figures with private timber owners since it was mandatory that each owner be contacted and a signed agreement as to exact ownership secured before spraying began.

Photographic mosaics were prepared for each control unit and greatly enlarged for field use. Aerial photographs and maps of individual spray blocks were furnished to contractors and pilots for determination of logical flight patterns for each spray block and for use during spraying operations. At the end of each day, pilots indicated portions of spray blocks treated that day on a master mosaic or map at each airfield. A different color was used for each day so that spraying progress could be readily determined.

Spraying Operations

Spraying for spruce budworm control must be closely supervised. Operations normally began at official time of sunrise and continued for 3 to 6 or more hours or until wind velocities reached 6 miles per hour, or temperatures reached 68° F. Pilots often shut themselves down before these limits were reached because of rough air. Control of spray pilots was provided by observation pilots and supervisory personnel. These men were in the air almost constantly checking them for position and checking the behavior of the insecticide. When spray patterns began to "break up," usually as a result of rising temperatures, pilots were ordered to stop spraying.

Pilots were instructed to fly at 75 to 250 feet above the treetops. However, some latitude was allowed on units with rugged terrain, and in deeply dissected canyons. Usually, overlapping lines were flown along contours. In steep canyons, cross-patterning of slopes on downhill flights completed the spraying operation. In most cases spray planes operated singly, one plane to a spray block. However, tandem spraying was also successfully used. This was done mostly as a safety measure while treating remote blocks.

Split-second timing and close teamwork by ground crews were provided at each airfield. Planes were loaded with insecticide and gasoline in the least possible time to permit as many flights per spraying day as possible. Emergency repairs to pumps and spray booms were quickly made to avoid loss of spraying time.

At the end of each spraying day, all planes received careful inspection by certified mechanics. These men often worked all night to have planes ready for the next day.

Spraying operations are regulated by larval development. They have begun as early as May 21 and ended as late as July 27. Most of the treating has been done in June and July, with the bulk of the acreage on a project usually being sprayed during the last 10 to 15 days of operations. On practically all projects, spraying was suspended several days after starting in order to wait for larvae to reach proper treating stages. This was necessary because development differed according to elevation and exposure, being most retarded at high elevations and on north slopes.

Technical Supervision

Technical supervision of control work (18) was the responsibility of the Division of Forest Insect Research, Forest Service, U. S. Department of Agriculture (formerly the Bureau of Entomology and Plant Quarantine). Briefly, technical supervision included:

(1) testing of ingredients used to formulate the insecticide,

(2) testing of formulated insecticide for DDT content,

(3) determining the start and sequence of spraying operations, and

(4) determining the results of control.

The first two activities were conducted in close cooperation with chemists of the Agricultural Research Service, U. S. Department of Agriculture, at Yakima, Wash.

Long before spraying began, during actual operations, and after spraying ended, a great many biological observations were conducted. These may be grouped briefly as follows:

(1) Determination of status of overwintering populations. An annual determination of the effects of low winter temperature on hibernating larvae on units proposed for treatment was necessary. This was done in February and March. Samples of bark and limbs containing overwintering larvae were collected from many spots on each unit and this material placed in sealed boxes in warm, lighted

rooms to force larval emergence. As much a 2-1/2 tons of limb samples were handled during a single year. Daily collections of emerging larvae were made from each box until emergence stopped. Results obtained were used in determining the status of populations and the final need for control.

(2) Determination of the start and sequence of spraying operations. One or more control districts, each including several units, were established for each project. A Biologist, under the supervision of the Project Entomologist, was in charge of the biological work on each district. He, in turn, was assisted by 2 to 4 Insect Checkers, depending on the size of the district.

The Checkers made daily collections of 100 larvae from spots representing low, medium, and high elevations; varying stand conditions; and varying exposures of slope. These were turned over to the Biologist, who examined each collection and determined percentages of larvae in each instar by microscopic measurements, or by visual comparison with predetermined larval standards. Daily progress of budworm development was charted and predictions were made as to when spraying should begin on each spray block and unit. To determine the sequence of operations, larval collections were continued until all spray blocks were released.

From 7 to 10 days notice prior to start of spraying was requested by the Project Director and the contractors. This request was made so that planes and pilots could be assembled at airfields, final checks completed on spray planes and equipment, and plans made for completion of numerous last-minute details.

"Zero hour" for each unit arrived when the highest percentage of larvae reached the 5th instar and when new foliage was at least 1/2-inch long. When these conditions occurred, a large percentage of the remaining larvae were in the 4th instar, with a small percentage in the 6th, and hardly any in the 3rd. In any one place or elevational zone, budworm remained susceptible to spraying for only about 10 to 12 days.

(3) Determination of control results. Control results were determined in several ways:

a. By checking spray deposits on glass plates or dye-treated cards

b. By checking larval survival on mortality lines

c. By spot checks throughout the unit

d. By comprehensive surveys for several years following spraying.

One or two days before spraying, employees known as Unit Spray Checkers, operating from each airfield, put four-inch-square glass plates or dye-treated cards in the blocks to be sprayed. Placed along compass lines at right angles to predetermined flight lines, these plates or cards were used to check spray coverage. They were carefully examined immediately following spraying so that droplet size and uniformity of spray distribution could be determined. If several plates on a given line were untouched by spray and Biologists found little larval mortality in the immediate vicinity, contractors were required to respray that portion of the block. Fortunately, there were few instances where respraying was necessary as the pilots did outstanding jobs.

Immediately before spraying, technical personnel installed mortality lines at right angles to flight lines in blocks released for treatment. A mortality line consisted of 10 stations. These were spaced 330 feet apart if established on a compass line, and 0.2 miles apart if established along roads. To determine populations prior to spraying, 10 branches 15 inches long (2 from each of 5 trees) were clipped over a collecting cloth at each station and all budworm larvae and pupae counted and recorded. Ten days after spraying, poopulations were again determined at these stations. At this time, however, the sample was doubled and 20 similar branches (4 branches from each of 5 trees) were clipped at each station and examined for surviving larvae or pupae.

During the seven-year period 1949-55, a total of 307,765 budworms, (307,600 larvae and 165 pupae) were collected before spraying. After spraying, only 5,604 budworms (4,711 larvae and 893 pupae) were collected. In other words, the budworm populations were reduced by 98 percent as a result of the spray program. Mortality during the different years ranged from 96.9 to 99.2 percent (Table 1). Many spray blocks showed 100 percent kill and only an occasional small block fell below the 90-percent level, which was considered to be the minimum degree of control.

Table 1.--Mortality and cost of spraying, spruce budworm control program in Oregon and Washington, 1949-55

Year	Acres Treated	Cost	Cost per acre	Mortality (percent) Range	Average
1949	266,000	$ 320,000	$1.20	88.9-100	97.6
1950	934,000	990,000	1.06	90.4-100	99.2
1951	927,000	983,000	1.06	74.0-100	98.6
1952	655,000	681,000	1.04	81.8-100	98.2
1953	369,000	350,000	.95	88.5-100	99.1
1954	68,000	63,000	.93	96.3-100	99.0
1955	621,000	658,000	1.06	79.0-100	96.9
Total	3,840,000	$4,045,000		74.0-100	
Average (wtd.)			$1.05		98.2

STATUS OF THE SPRUCE BUDWORM AFTER 7 YEARS OF CONTROL

After 7 years of intensive control efforts, the spruce budworm picture in Oregon and Washington is fairly bright.

Major accomplishments of this important control program can be summarized as follows:

(1) A total of 3,840,000 acres of the most critical areas of epidemic infestations has been successfully treated at a cost of about $4,045,000, or approximately $1.05 per acre.

(2) The total area of completely dead timber resulting from budworm defoliations has been confined to less than 10,000 acres.

(3) An epidemic that started in 1944 and reached a peak of 2,276,000 acres in 1949, has been reduced to 543,000 acres in 1955. This was the lowest acreage of epidemic infestations since 1946.

(4) Epidemic infestations of the budworm have been eliminated in the western Oregon area and from the eastern slopes of the Oregon Cascade Mountains during a period when a strong tendency existed for the budworm to increase on unsprayed areas.

(5) Less than 1 percent of the area treated to date has had to be resprayed because of budworm reinfestation.

(6) Recovery of defoliated trees after treatment has been remarkable and has proved the program's value.

(7) Valuable watersheds have been protected, and creation of an immense forest fire hazard has been averted.

(8) The practicability of aerial spraying to control the budworm at a reasonable cost per acre has been fully demonstrated.

Prior to 1955 there had been local indications of the increasing effectiveness of natural control factors (4). Some 33 species of primary parasites have been recovered from the budworm in Oregon and Washington. Included in this list were: 1 species from eggs, 5 species from 2nd instar larvae, 19 species from mature larvae, and 8 species from pupae. In spite of these parasites, the budworm has maintained a high epidemic population on unsprayed areas. On units treated since 1949, control has remained effective and reinfestation has been insignificant.

In 1955 aggregate parasitism was noticeably higher than in previous years. Of even greater significance was the recovery of the hymenopteron, Meteorus trachynotus Vier., from mature larvae from 3 separate areas in Oregon. Entomologists in Canada and the northeastern states feel that this species, normally rare in occurrence, is one of the primary indicators of a downward trend in budworm populations (6, 11).

This improvement in the budworm parasite complex in 1955 was most encouraging. Our 1955 surveys (19) showed a declining infestation and a reduced threat of extensive tree-killing by the budworm. Therefore, the Action Committee recommended a suspension of aerial spraying operations in 1956. For the first time in 7 years there has been a break in the control program.

Control of the budworm in Oregon and Washington was undertaken as a stop-gap measure to protect specific values until natural factors again became fully operative. We are extremely hopeful that the significant trend in effective parasitism, observed in 1955, will continue and that the epidemic may be over.

At the present moment regional surveys and research studies are being conducted to re-appraise the spruce budworm situation. Results will be carefully evaluated and a decision made whether to resume or again suspend the aerial spraying program in 1957. We hope we are out of the spruce budworm control business.

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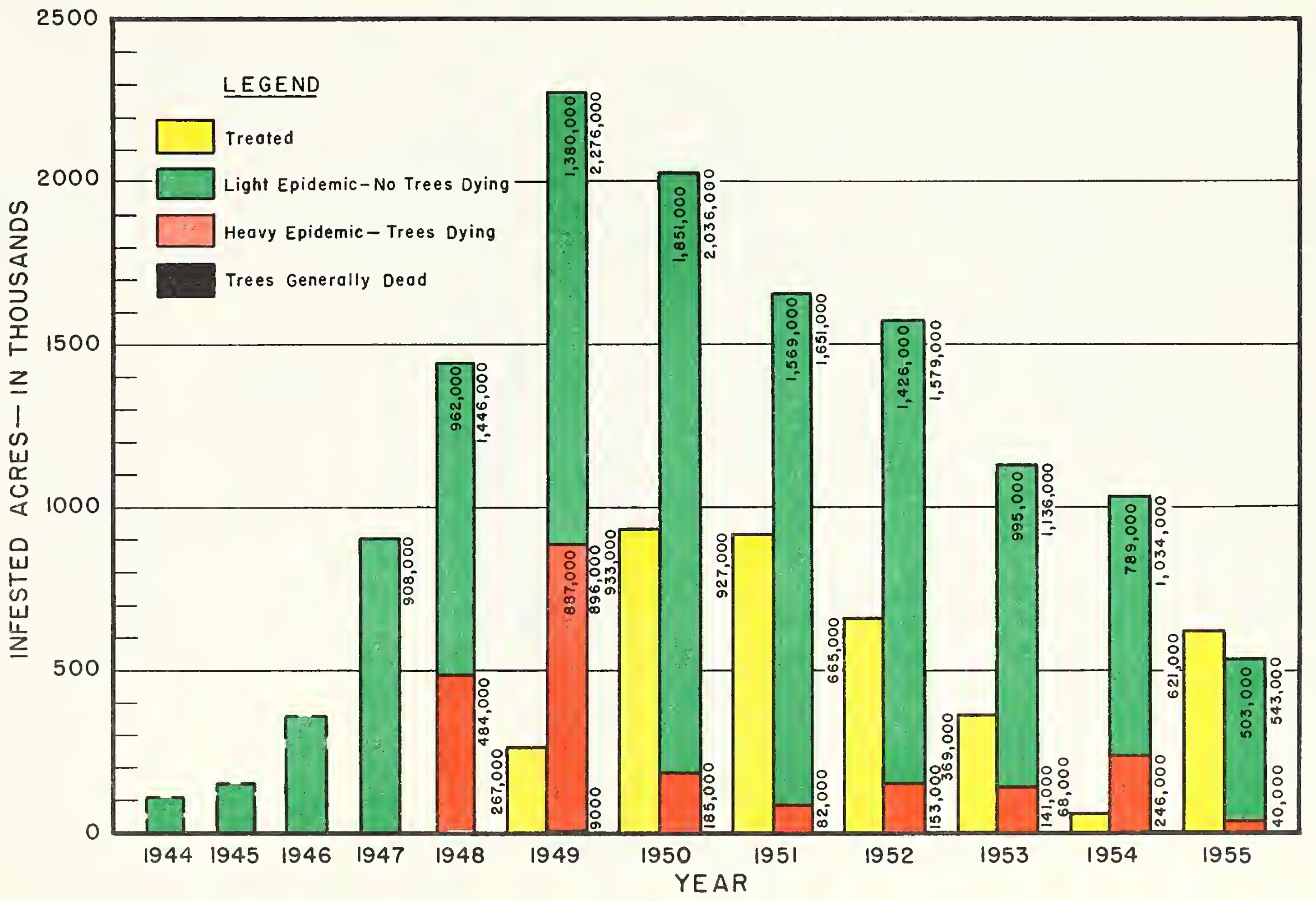
GRAPH I

PROGRESS OF SPRUCE BUDWORM EPIDEMIC IN OREGON AND WASHINGTON



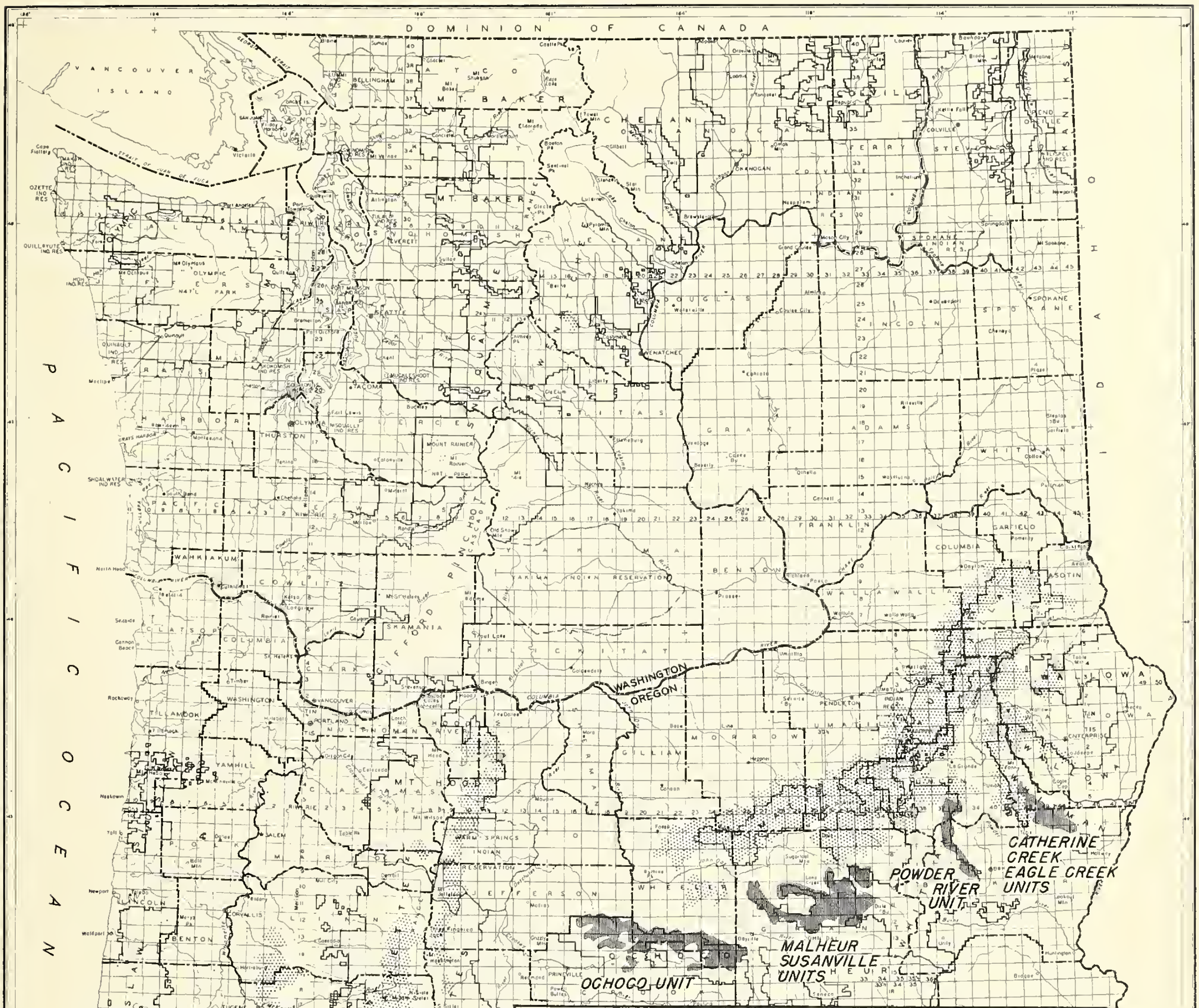


FIGURE-I
SPRUCE BUDWORM CONTROL PROGRAM IN OREGON AND WASHINGTON
1949–1955
LEGENO
Control Units Treated in 1955 620,947 Acres
Aeriol Spraying Projects of 1949–1954 3,218,664 Acres
OCHOCO Name of 1955 Control Unit
Program recommended by
NORTHWEST FOREST PEST ACTION COMMITTEE
Control administration by
U.S. FOREST SERVICE
OREGON STATE BOARO OF FORESTRY
WASHINGTON STATE OIVISION OF FORESTRY
Technical supervision by
PACIFIC NORTHWEST FOREST ANO RANGE EXPERIMENT STATION
1956
CATHERINE CREEK EAGLE CREEK UNITS
POWDER RIVER UNIT
MALHEUR SUSANVILLE UNITS
OCHOCO UNIT
DOMINION OF CANADA
PACIFIC OCEAN
WASHINGTON
OREGON
IDAHO
CALIFORNIA NEVADA
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
LYLE F. WATTS, CHIEF
ANTHONY P. DEAN, CHIEF, DIVISION OF ENGINEERING
NATIONAL FORESTS OF REGION 6
(PACIFIC NORTHWEST REGION)
1951
LAMBERT PROJECTION